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M N Hough

Spring Frosts in South West Lancashire

The low lying peat soils between Ormskirk, Preston and Southport make very productive land for vegetable cropping. At first sight the maritime climate is favourable, but growers and advisers consider that early cropping, especially potatoes, is restricted by the risk of late frosts.

Some notable local crop failures due to frost have occurred. On the night of 22-23 June 1957 early potatoes were damaged on peat soils, but not on sandy soils. On this occasion cool air from the north east was accompanied by clear skies and dewpoints of 3 or 4°C. Grass minima of -1°C were reported from Squire's Gate and Ringway. In 1975 some potato crops were wiped out after a frost on the morning of 29 June. Dew point temperatures were around 3°C and Squire's Gate reported a grass minimum of -1°C.

In order to investigate the pecularities of the climate of the peat soils, a climatological station was established at Martin Mere (NGR SD 421 146) in Spring 1978 (J Tyldesley, personal communication). Standard climatological observations have been made there, which make it possible to compare temperature readings with other stations nearby (Squire's Gate and Aughton). Table 1 shows the differences in monthly mean values of daily air minimum temperature.

Table 1 - Martin Mere minus Squire's Gate air minimum

	April	May	June
1978	N/A	-1.5	-2.5
1979	-1.1	-0.7	-1.0
1980	-0.6	-0.7	-1.1
1981	-0.3	0.0	-0.8
1982	-1.1	-0.8	-1.1

FH2B

Martin Mere minus Aughton air minimum

	April	May	June
1979	-1.3	-0.4	-1.0
1980	-0.9	-1.9	-1.2
1981	-0.9	-0.7	-0.5
1982	-2.0	-1.9	-1.3

These tables show that Martin Mere on the peat soil has lower screen minimum temperatures than surrounding stations. Nearly all these temperature differences are statistically significant, some highly so.

A similar analysis for the grass minimum temperature is not so striking. The temperature differences are usually small and non-significant and of either sign. It seems then that on radiation nights the surface temperature behaves similarly (though there are notable exceptions to be discussed later), but that a greater cooling extends at least to screen height at Martin Mere. This is probably due to the situation of the stations since Squire's Gate is a coastal airfield which is subjected to the influence of the sea and Aughton is on a hill. Martin Mere is low lying and would be expected to receive cold air drainage from hills to the south east on radiation nights.

One feature of the table is the possible effect of dry soil on temperatures. It is well known that dry soils have a lower thermal conductivity than wet soils so that dry conditions may increase the temperature differences. Of the years in the table 1980 and 1982 both had dry Aprils and Mays while 1981 was wet. The table shows that temperature differences were small in the wet year (1981), and larger in the drier years.

Soil Temperatures

Temperatures at 10, 20 and 30cm depths were available at Martin Mere, and for some of the time at Aughton. The soil at Aughton is a mineral soil. In general the soil at Martin Mere is cooler in summer, but warmer in winter than at Aughton. The temperature differences are usually small (less than $1^{o}C$) but statistically highly significant.

These results can be interpreted in terms of the low heat conductivity and high heat capacity of peat soil compared with mineral soils. Therefore, when conditions are warming up in spring we expect the peat soil to warm up at a slower rate so that temperatures at 30cm say, are lower than temperatures at the same depth in a mineral soil. Conversely, in winter when the environment is cooling, the reverse takes place

and the peat is warmer. This lag effect can be seen in individual warming/cooling cycles during a month. Figure 1, for February 1980 shows a warming situation in the first part of the month and the peat soil temperature only "caught up" at the end when a cooling took place. The same thing happened to a much greater extent in May 1980. Rainfall had been very low in April so that the top soil was dry. The prolonged sunshine between 8 and 19 May caused a warming situation (figure 2). The temperature of the peat soil never caught up during the month. The overall rise in temperature during the warming was 2.7°C for the peat and 4.2°C for the soil at Aughton. This difference is due mainly to the higher heat capacity of the peat soil. These graphs (figures 1 and 2) show that at 30cm depth the peat soil takes 2 or 3 days to respond to a temperature change. At shallower depths the response is a bit quicker.

Further investigation of Air Temperatures at Martin Mere

The climatological data showed that occasionally there were large local temperature variations between the stations, usually with Martin Mere colder at night. There is often a relationship between large local temperature variations and the weather conditions at the time. This was investigated for the two places Martin Mere and Aughton by using occasions when the air minimum and grass minimum temperature differences between the two places exceeded 3°C. Table 2 gives a breakdown of the number of occasions from November 1979 to June 1980, according to whether Martin Mere was 3°C colder or warmer than Aughton.

The first common feature is that most of these occasions of large differences in temperature had light winds. On two occasions the wind was light at Martin Mere only. Clear skies were important for causing large differences, especially when Martin Mere recorded lower air minima. However, Martin Mere was sometimes much colder on nights with only a few clear intervals.

Table 2

The number of occasions when temperatures at Martin Mere were 3°C different from those at Aughton. (November 1979 to June 1980).

Air Minimum	More than 3°C higher at Martin Mere	More than 3°C lower at Martin Mere
Mainly cloudy with a few breaks	3	6
Mainly clear skies	0	18
Grass Minimum		
Mainly cloudy with a few breaks	0	10
Mainly clear skies	6	16

All the grass minima, and two thirds of the air minima in table 2 occurred on mainly cloudy nights when Martin Mere recorded the lower temperature. This may indicate a more rapid response at Martin Mere to night time cooling during clear periods of one to two hours duration. This would follow because peat soil is a poorer conductor of heat than a mineral soil. If skies remain clear all night, then there is time for the cold air to drain with the coldest air going to the lowest place. It seems then that there might be two processes which give low temperatures at Martin Mere, one process for short clear periods, and the other for clear skies all through the night.

An attempt to resolve these questions was made in spring 1981 and 1982 by using equipment to measure temperatures at frequent intervals.

Layout of Equipment

Temperatures were measured every half hour using a Grant temperature recorder. The sensing elements were mounted in "cocoa tins": one to measure air temperature at 1.2m above ground, two on the grass with the temperature sensor about 3cm above the soil surface, and one on the bare soil of the bare plot in the enclosure. All thermometers were calibrated against an inspectors thermometer in a water bath before and after the measuring period. The Grant recorder was housed between the legs of the Stevenson screen stand, in plastic bags and cardboard boxes, and all wiring was buried. Recordings were made between 9 April and 9 June 1981, and between 14 April and 27 May in 1982.

Measurements in 1981

March was very wet (400% of average rainfall) and mild so that there was a good cover of grass by early April. April was drier (75% of average rainfall) and the soil moisture deficit under grass increased from near field capacity in early April to 30-40mm deficit by about 21st. After this, cold, wet weather followed and the soil was brought near field capacity again. May was wet (140% of average) and deficits did not reach high levels. The Martin Mere area has ponds and other surface water features which amount to 15-20% of the total area. In spring 1981, the excessive rain increased the free water area to something like 30% and the soil was wet as well.

Mole activity was high in the enclosure and two of the ground level cocoa tins were partly buried. This invalidated most of the data for May, so nearly all the results are for April only.

Results

Nights were chosen from the records which had cloudy skies all night, cloudy skies with

a few breaks, and clear skies all night. The diagrams (figures 3 to 10) show data for the three classes of night. The grass temperatures are the average of two readings, for although the two grass temperature cocoa tins were only 6ft apart, differences of up to 1°C were sometimes found.

Cloudy nights

The night 12-13 April was cloudy all night with rain at times and a NE breeze. Temperature differences were very small (below 1°C) and the difference between Aughton/ Martin Mere was also small. The night of 23-24 April was also cloudy with a moderate SE wind. Rain and sleet were reported. Although the bare soil and grass temperatures were higher than air temperatures in the sunny later afternoon, the temperatures quickly became very similar when the cloud spread over.

Partly cloudy nights

The night of 11-12 April was mainly cloudy after a showery day, but cloud cleared between 21.00 and 22.30. When the cloud cleared, the grass temperature fell by nearly 3°C in 1.5 hours. The air temperature at 1.2m fell 1°C at the beginning, but not at all afterwards. The layer of cooled air close to the ground warmed up when the cloud layer became re-established.

The night of 20-21 April was in fact substantially clear until 01.00 when a cloudy period caused warming both at the surface and at 1.2m. Clear skies after 02.30 allowed rapid cooling: 3.5°C in 0.5 hour at grass level between 02.30 and 03.00. Cooling at 1.2m was less and tended to be concentrated in the early part of the clear period.

Clear Nights

Many studies of night cooling under clear skies in UK have shown that there are two distinct sections to the cooling curve. The first part is a period of rapid cooling which occurs before and after sunset. There is then a reduction in the rate of cooling at about 20.00 to 21.00 hours, which continues until dawn. This change in the cooling rate is observed at ground level and in the air above and is thought to be due to the release of latent heat as dew or frost forms on the grass. It is obvious that a moist layer of air will reach the condensation point earlier and experience less cooling than drier air. The measure of air moistness is called the dew point temperature of the air, and it is the lower of the two numbers in the Aughton observations.

In the night of 14-15 April cooling from 18.30 to 20.00 was fairly rapid, but after 20.00 the cooling was less rapid. The break in slope takes place at a temperature of 8°C which is therefore the dew point of the air at Martin Mere. After midnight a dramatic drop in temperature occurred (6°C in an hour at ground level) and this air remained until it was warmed by the rising sun. This rapid cooling cannot be due to local cooling of the air at Martin Mere since there was a much slower rate of cooling before midnight. It can be explained if colder air replaced the Martin Mere air. A cooling curve sketched in for the colder air suggests that it had a dew point of about 2°C. We note that the dew point at Aughton fell from 6 to 2°C during the early part of the night.

The night of 15-16 April shows that the slow rate of cooling for the air at Martin Mere extended for all of the night. Some broken cloud caused warming after 04.00. At 22.30 and 23.00 some anomalously cold temperatures were measured which were quite out of character with the rest of the cooling curve. The invasion of colder air was apparently not complete on this occasion.

On the night of 19-20 April the cooling curve seems to show a dew point at Martin Mere of about 3.5°C. However, on three occasions colder air temporarily interrupts the steady cooling. On 2-3 May the cooling curve suggests a dew point of about 2.5°C, but it seems that there was not enough time for colder incursions to occur before cloud and rain eliminated temperature differences.

Air Humidity and Minimum Temperature

For reasons of conservation the water table is kept high at Martin Mere, and we have already noted the wet condition of the peat in the wet spring. By contrast, the farmed area around the Mere reservation is drained, and in spring there is a lot of dry, bare soil. Air in contact with these surfaces will have a lower dew point and consequently would cool to lower temperatures than air over the moist mere area. The temperature records show that this air replaces the Martin Mere air on some nights, but not all. The measurement site is about one third of a mile away from the drier farmland to the NE, E and S which are the most likely directions for katabatic flows. There is the possibility therefore that minimum temperatures at Martin Mere are not always representative of the surrounding farmland.

There were two occasions with large differences in air minimum temperature between Aughton and Martin Mere. These were 15 April (Martin Mere 4°C colder) and 9 May

(Martin Mere 4.9°C colder). On both these occasions there were marked incursions of the colder air. It has been noticed before that Martin Mere is on average 1°C colder (air minima) than surrounding stations. However, there is a secondary peak in frequency for larger temperature differences and this may be caused by the occasional incursions of much colder air.

Measurements in 1982

March 1982 was wet (200% of average), but April was drier (75% of average) and May was dry (70% of average). The soil moisture deficit under grass was close to field capacity in early April, but increased steadily from mid April to reach 75mm by 19th May. There was much less surface water about in 1982 compared to 1981 and the surface soil became dry.

Again, nights were chosen from the records which were either mainly clear or else cloudy with a few breaks. The graphs are shown in figures 11 to 15.

Clear Nights

The night of 14-15 April had small amounts of cloud and light winds. The grass temperature fell about 6.5°C in one hour between 19.00 and 20.00, with more gradual cooling after that. By 0600 the 1.2m air temperature at Martin Mere was 5°C colder than Aughton. The pattern was very similar on the night of 19-20 April, but on neither night was there much sign of replacement of the Mere air by colder air. The night of 5-6 May was also clear with low dew points. A sharp frost developed so that by 06.00 the 1.2m air emperature at Aughton was 4°C, but -3°C at Martin Mere. It is quite clear in this instance that the coldest air has drained down hill, leaving the hill top much warmer.

Partly Cloudy nights

On the night of 22-23 April a weak cold front crossed the area at about 20.00. Skies remained mainly cloudy afterwards except for a few breaks. At Martin Mere the cloud broke up at about 01.00 which allowed the temperature to fall; 3.5°C in half an hour was the maximum fall recorded a ground level. A slight ground frost was recorded for about an hour.

The night of 18-19 May was also partly cloudy with some large drops of temperature during clear spells. A fall of 8°C in one hour at grass level was recorded in the early part of the night.

During the recording period in spring 1982 there were five occasions with Martin Mere much colder than Aughton. Three of these were situations of broken cloud (two of them are described above), one was a mainly clear night (14-15 April (figure 11)), and the remaining occasion was a windy night with some cloud breaks.

Conclusions

1) Growers should be aware that the temperature close to the ground can drop very quickly in the first part of a clear night. Falls of up to 8°C per hour have been measured at Martin Mere. In addition a clear period of a few hours duration can allow the surface temperature to drop quickly even though the grower's thermometer at head height may only show a small fall.

2) Air which has cooled over adjacent dry areas is likely to be colder than air which has cooled over a moist surface. On a calm night this colder air will flow downhill and may displace the warmer air. These effects were more obvious in 1981 when surface conditions were very wet at Martin Mere.

Although it is not possible to say with confidence from these data that temperatures are lower due specifically to soil type, there is no doubt that the low lying position and poor conductivity of the soils does increase the frost risk. The critical time of year for frost damage to vegetables and potatoes is May and June. The conditions necessary for frost include air with low dew points (3 to 5°C) and clear skies and light winds to allow a rapid fall of temperature in the short summer night. Extreme falls of ground temperature at Martin Mere are near 8°C an hour, so only a few hours cooling would be required for a frost.

Acknowledgements

Dr J Kears, Head of the Wildfowl Trust, Martin Mere kindly gave permission for the siting of equipment. Mr Bob Read is Observer at Martin Mere and looked after the Grant recorder. Mr J Tyldesley originally suggested the study which was set up with the co-operation of Mr A Adamson of the Ormskirk Area Office.

Meteorological Office
Harrogate

January 1983

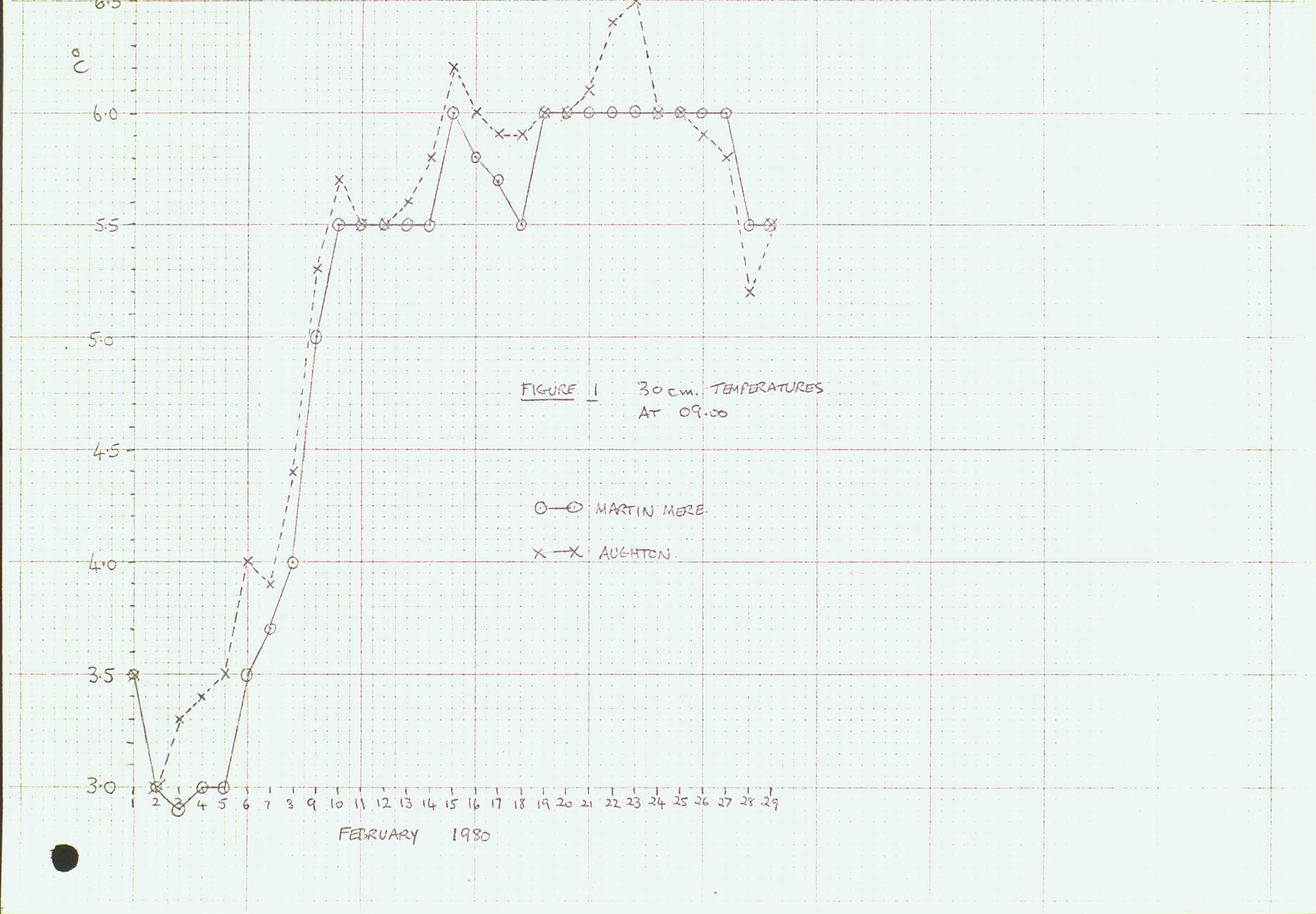


FIGURE 1 30 cm. TEMPERATURES AT 09.00

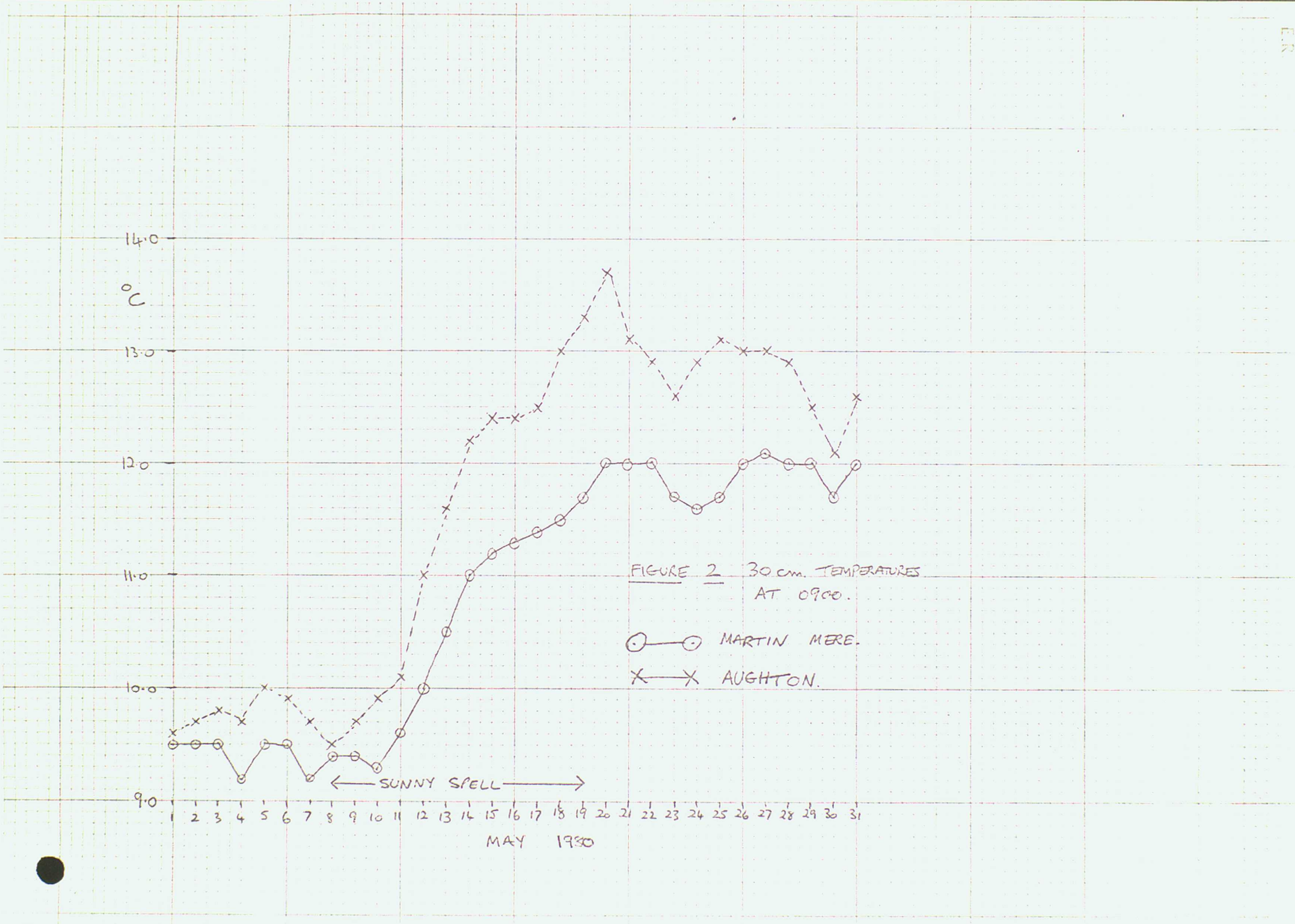
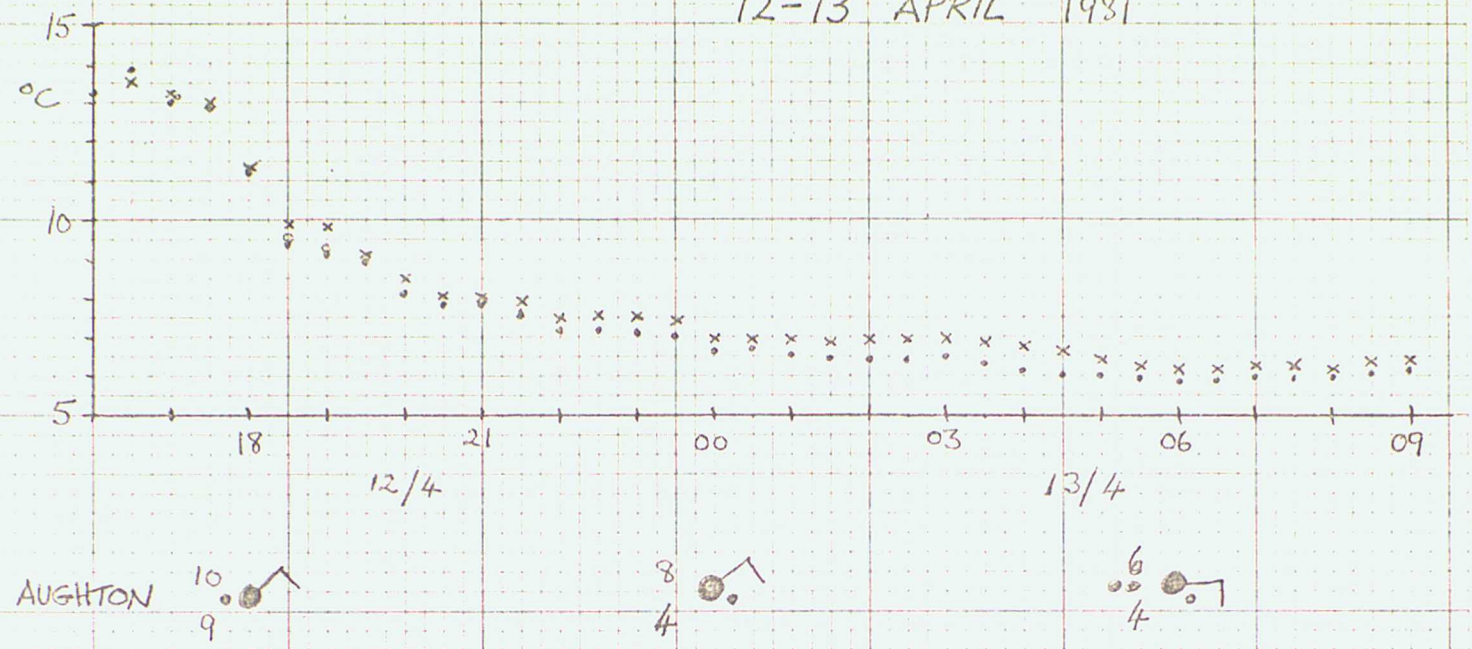


FIGURE 2 30 cm. TEMPERATURES AT 0900.

FIGURE 3

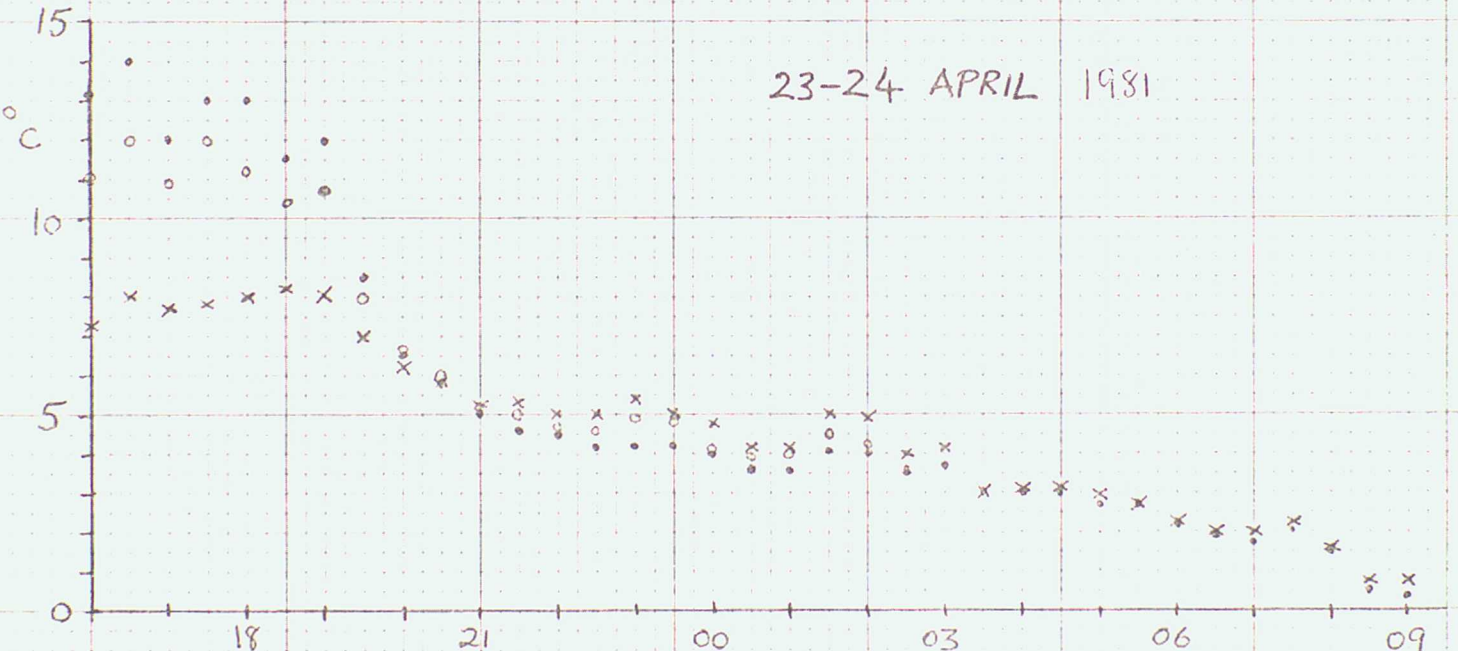
12-13 APRIL 1981



AUGHTON 10 9 8 4 6 4

FIGURE 4

23-24 APRIL 1981



AUGHTON 7 0 5 1 2 2

CLOUDY NIGHTS

• GRASS ○ BARE SOIL × AIR AT 1·2 m.

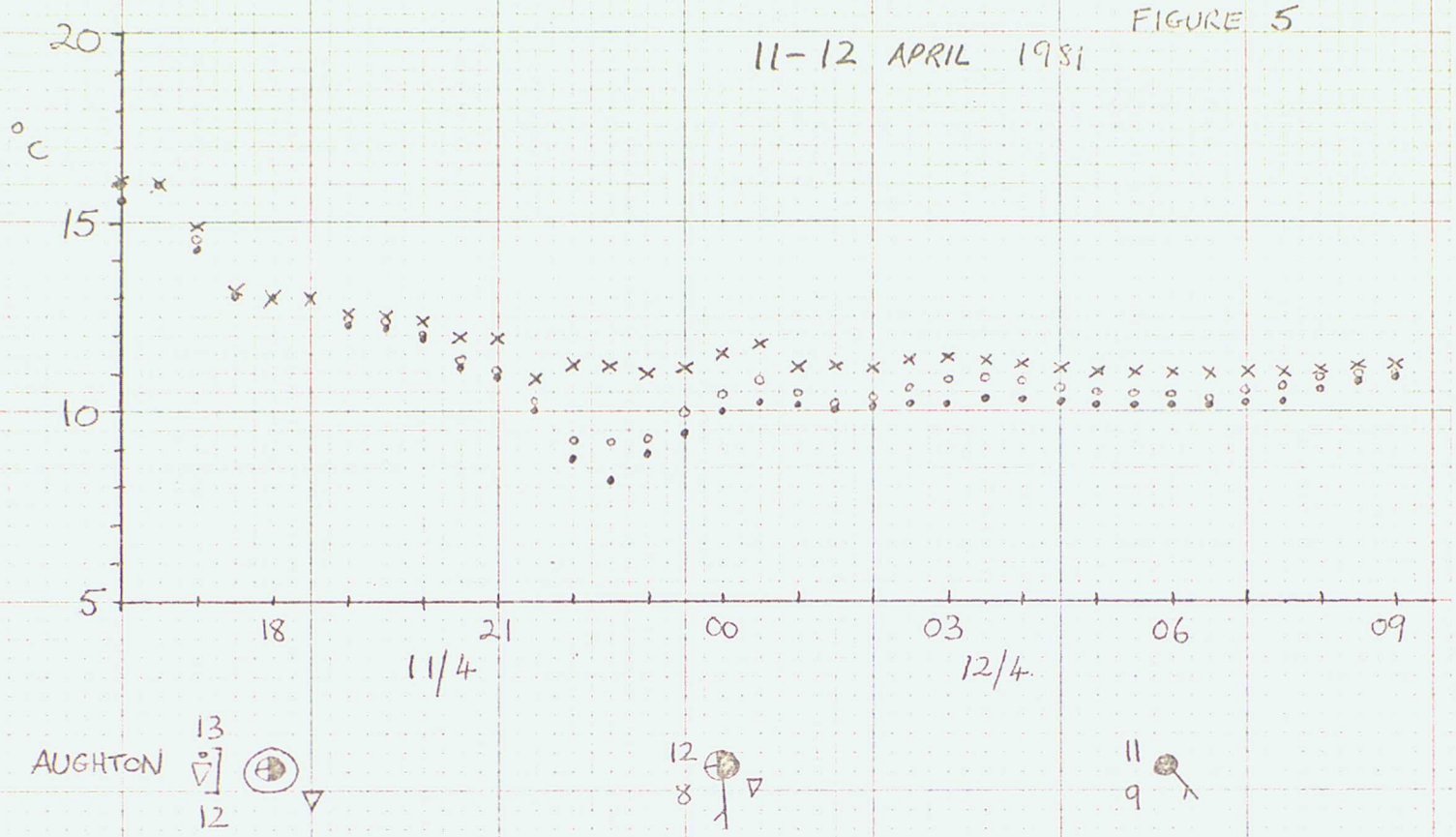
E.R.

PARTLY CLOUDY NIGHTS

• GRASS o BARE SOIL × AIR AT 1.2 m.

FIGURE 5

11-12 APRIL 1981



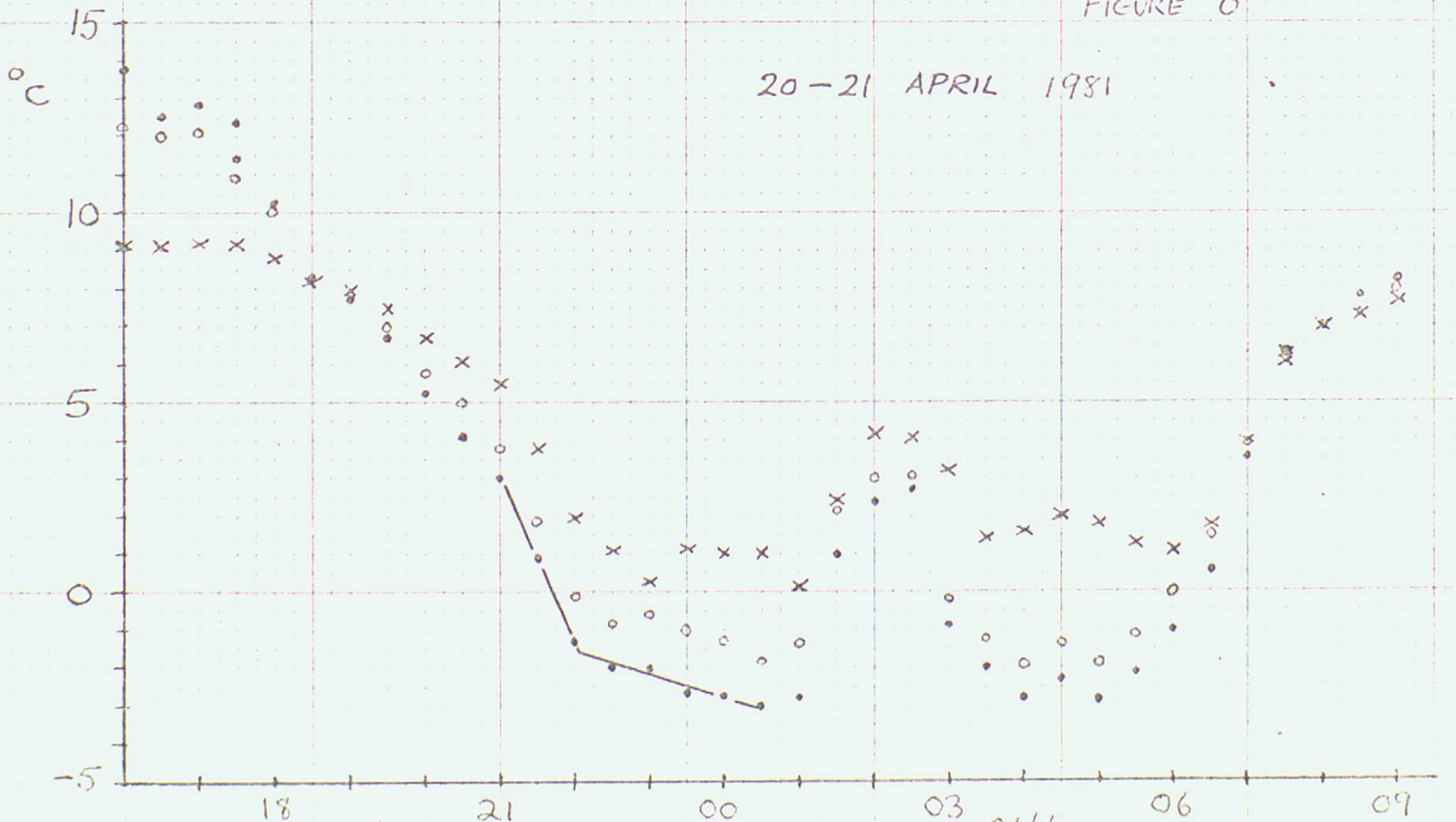
AUGHTON 13 12

12 8

11 9

FIGURE 6

20-21 APRIL 1981



AUGHTON. 8 2

4 3

6 5

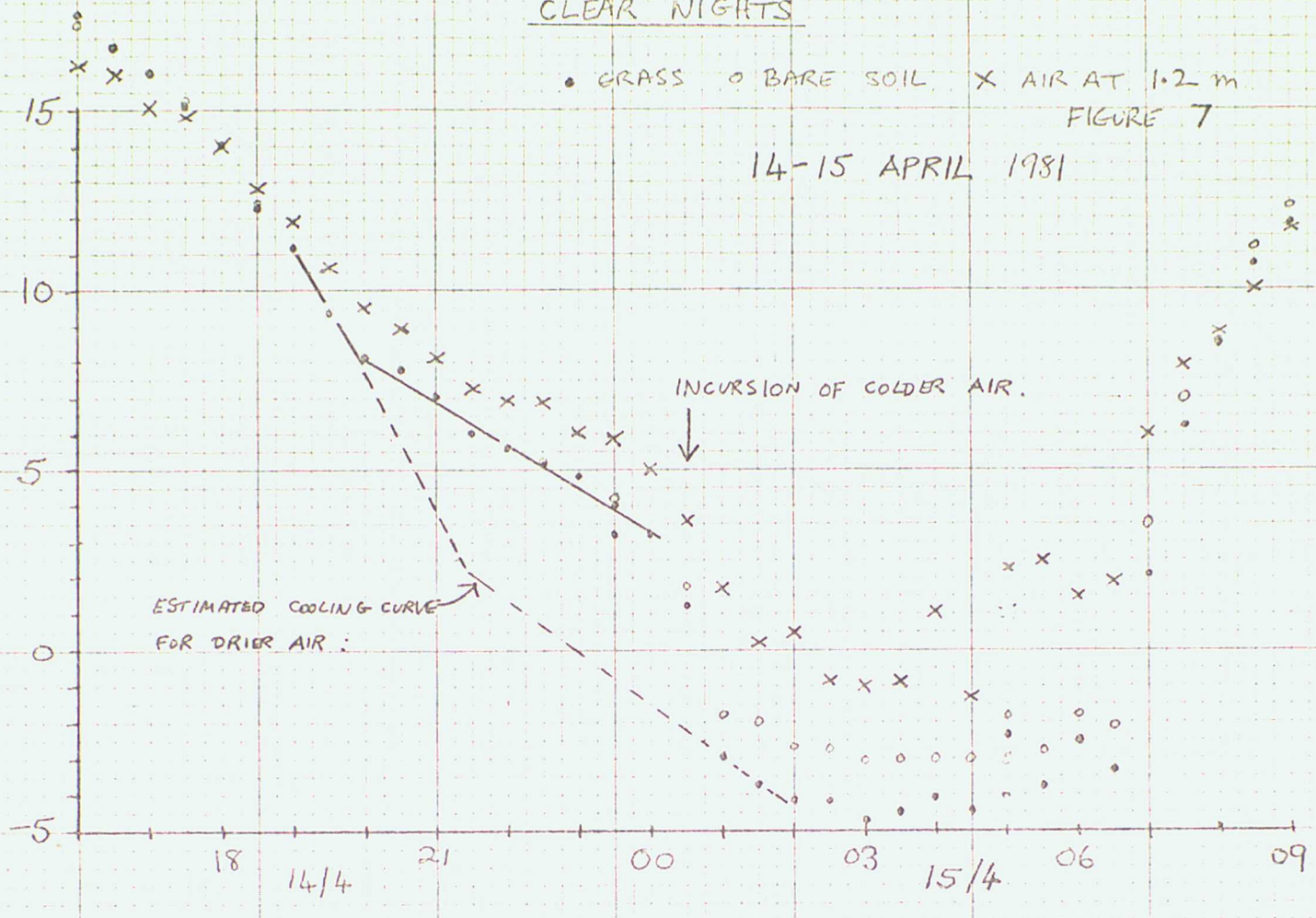
E.R.

CLEAR NIGHTS

• GRASS ○ BARE SOIL × AIR AT 1·2 m

FIGURE 7

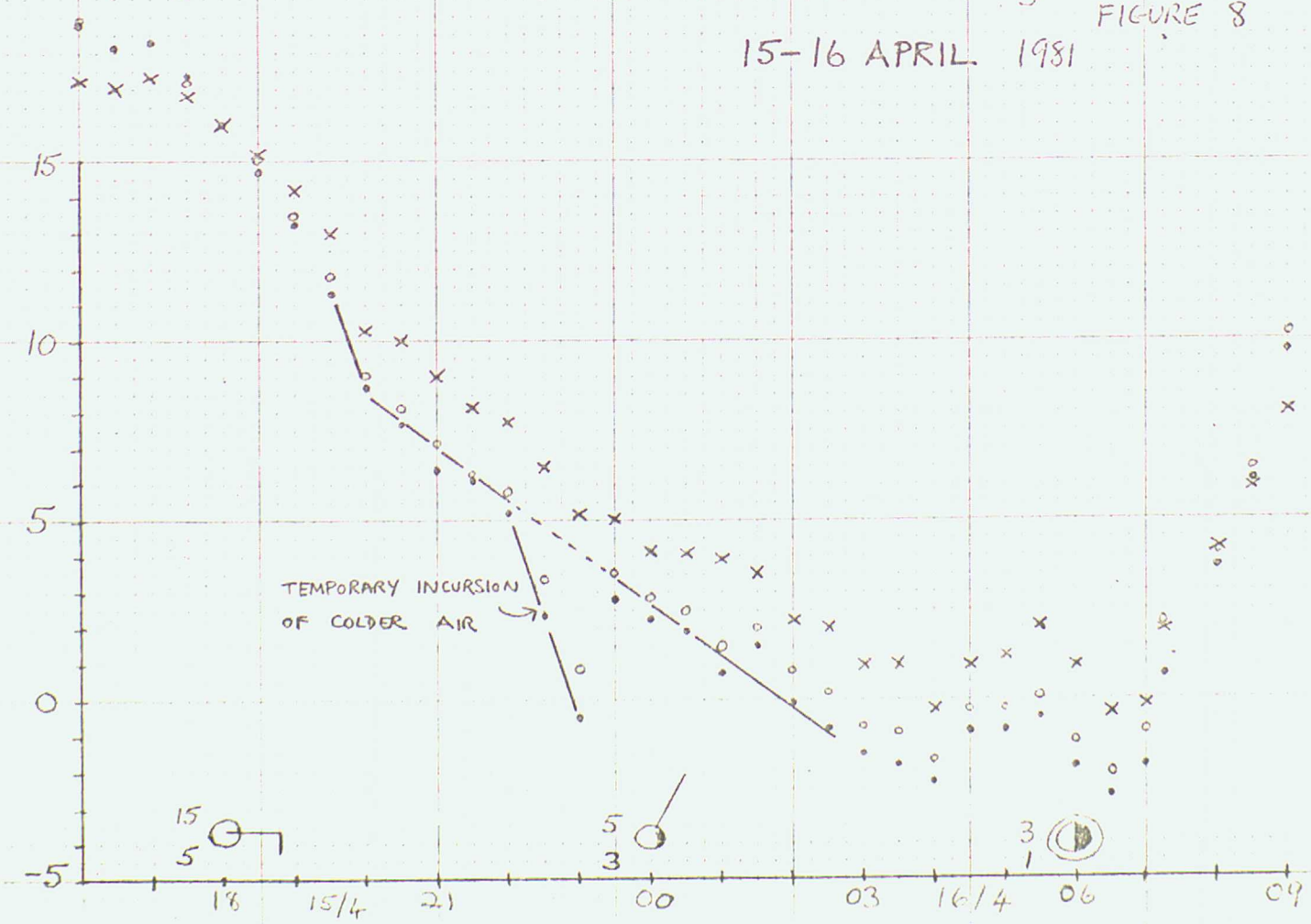
14-15 APRIL 1981



AUGHTON 12 6 | 5 2 | 6 3

FIGURE 8

15-16 APRIL 1981



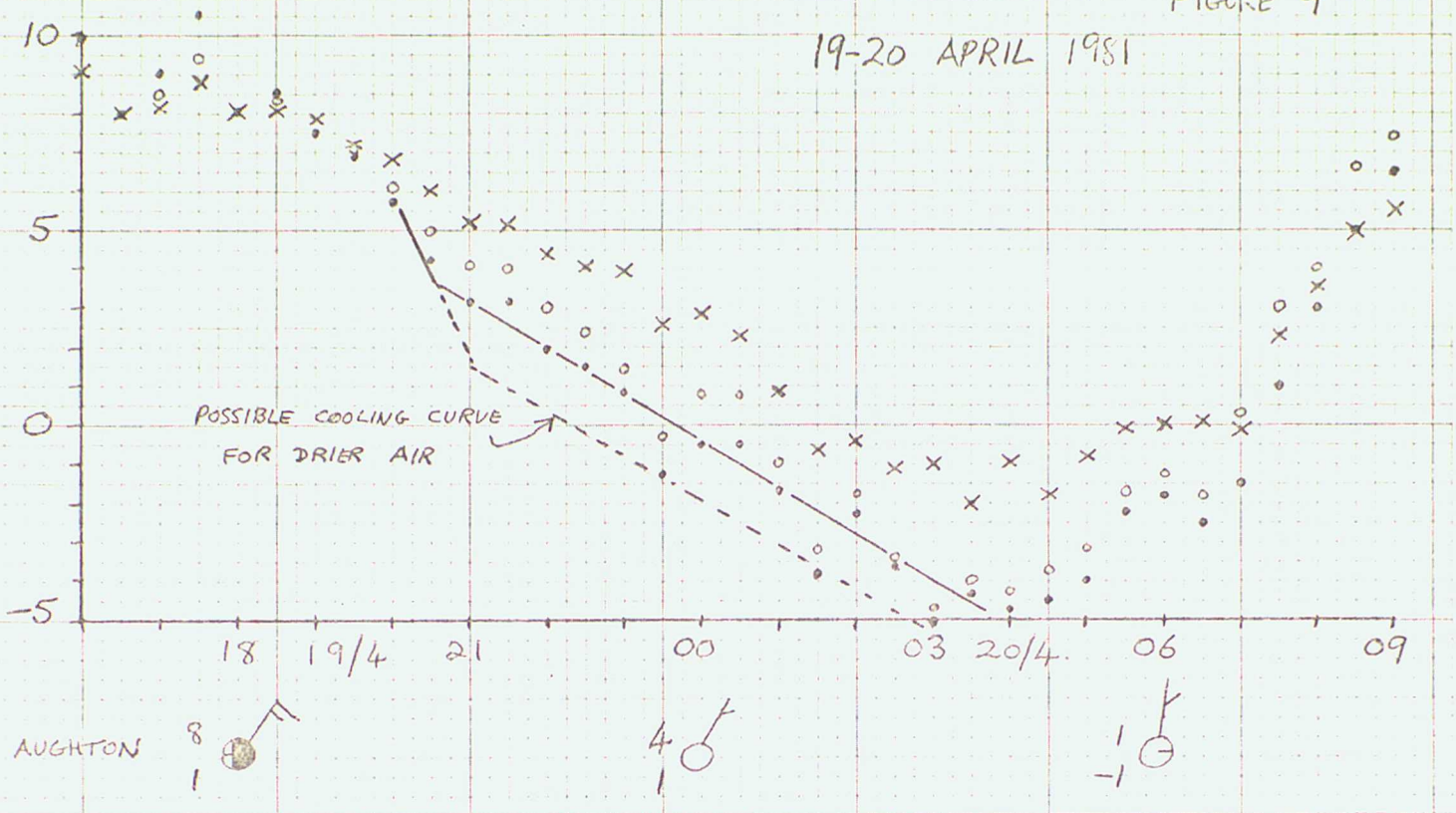
E.R.

CLEAR NIGHTS.

• GRASS ○ BARE SOIL × AIR AT 1·2m.

FIGURE 9

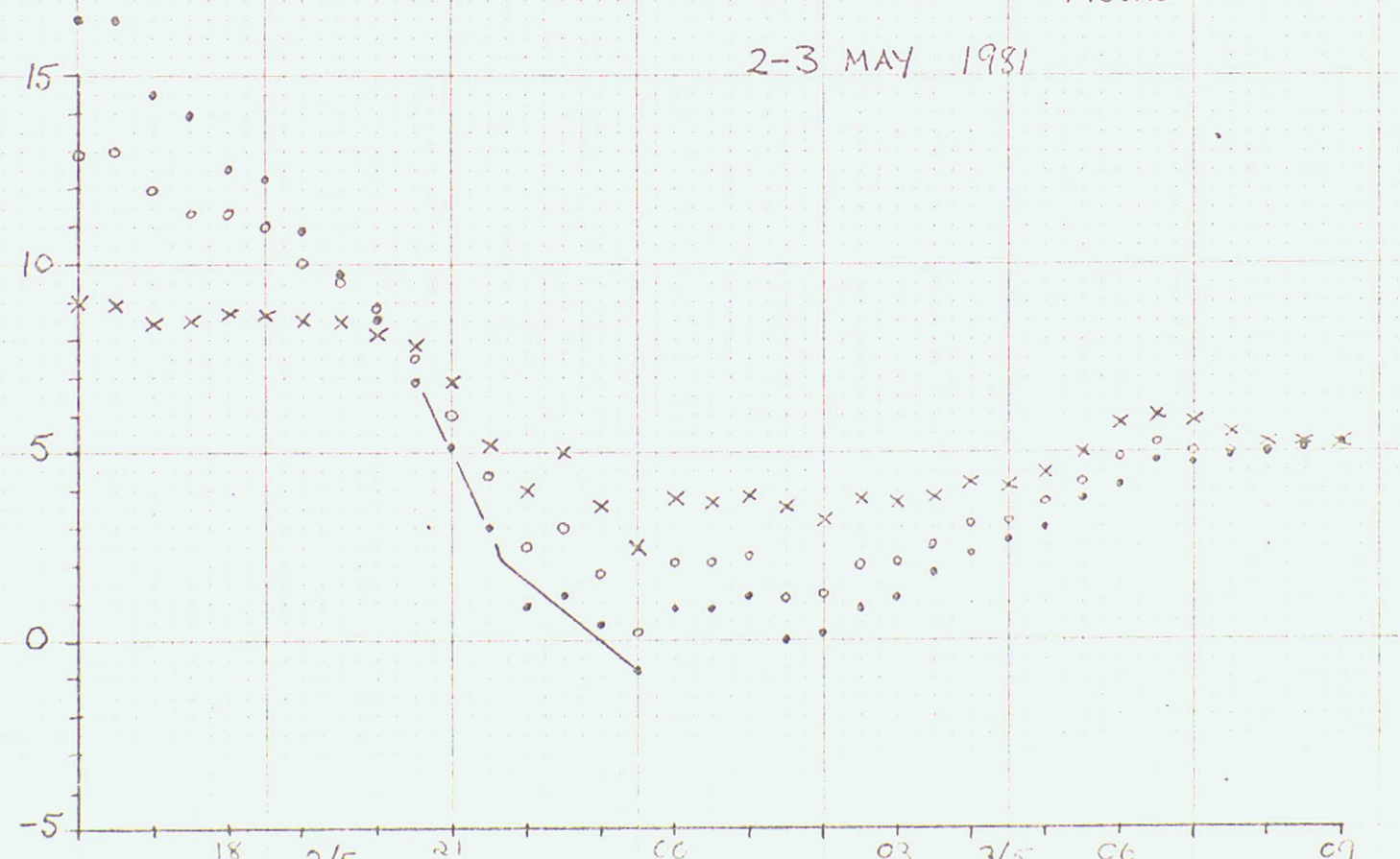
19-20 APRIL 1981



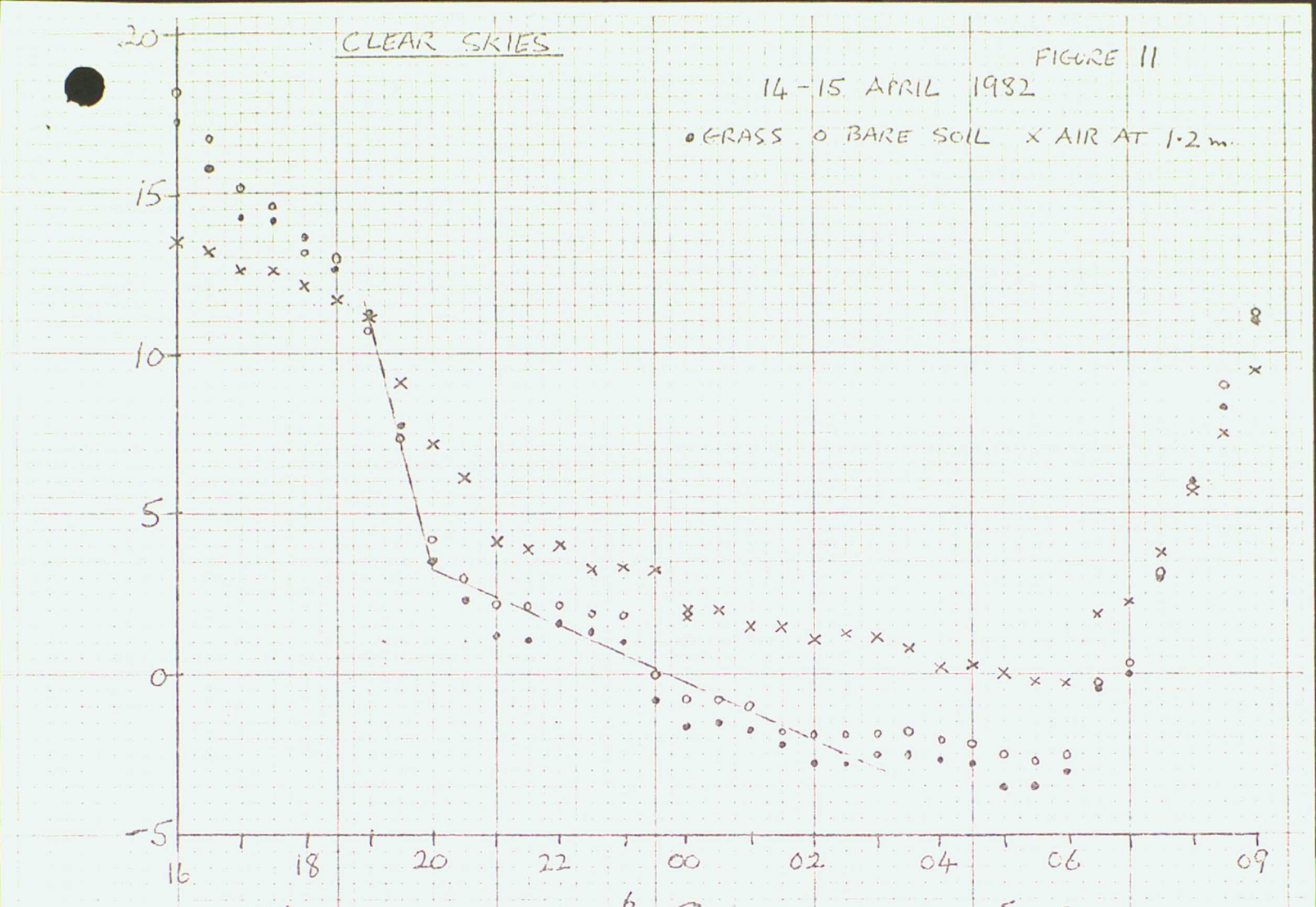
AUGHTON 8 1 4 1 1 -1

FIGURE 10

2-3 MAY 1981



AUGHTON 7 0 5 1 5 3


CLEAR SKIES
FIGURE 11
14-15 APRIL 1982
• GRASS o BARE SOIL × AIR AT 1·2 m.
20
15
10
5
0
-5
16
18
20
22
00
02
04
06
09
AUGHTON
10
7
6
5
5
4

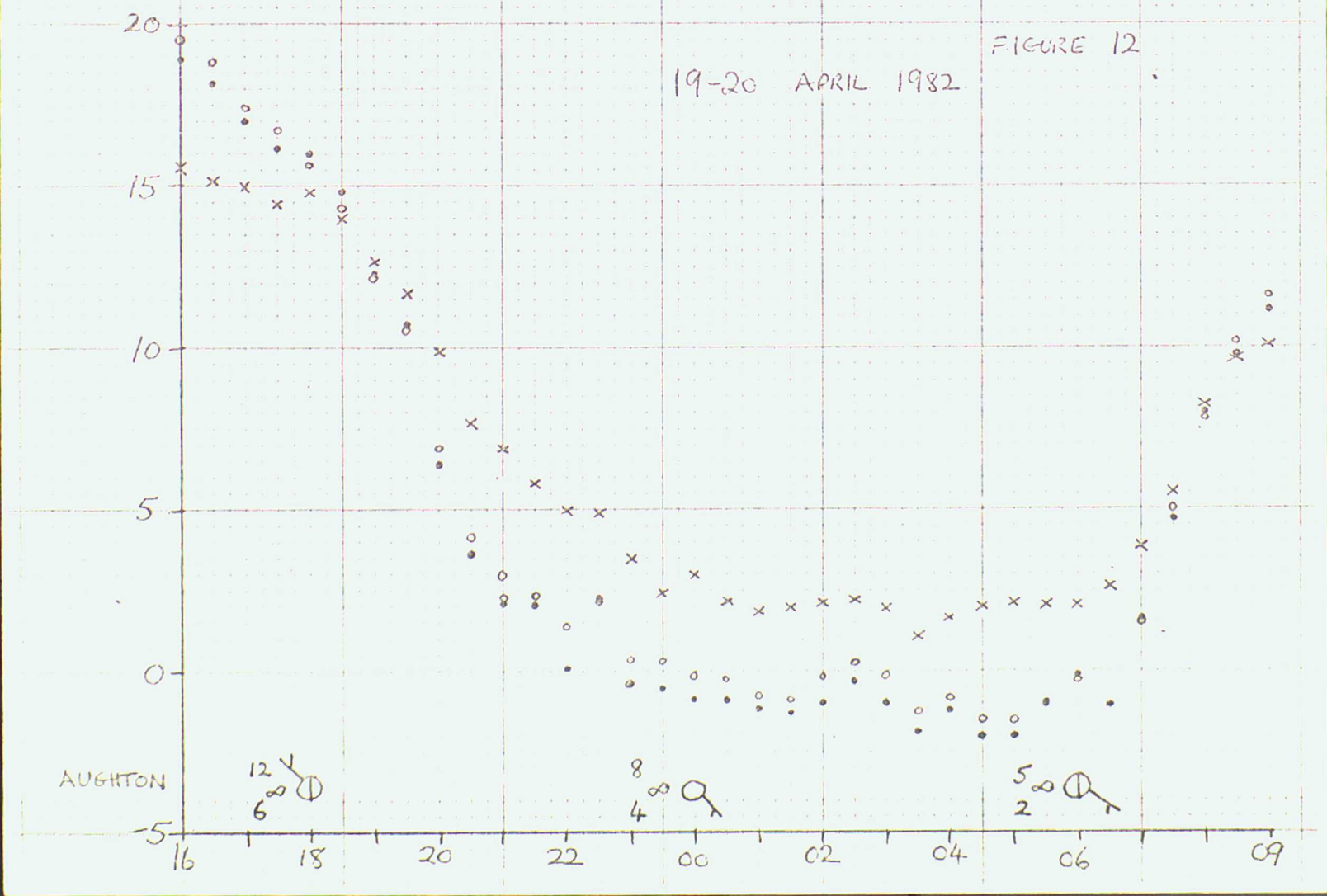


FIGURE 12
19-20 APRIL 1982
20
15
10
5
0
-5
16
18
20
22
00
02
04
06
09
AUGHTON
12
6
8
4
5
2

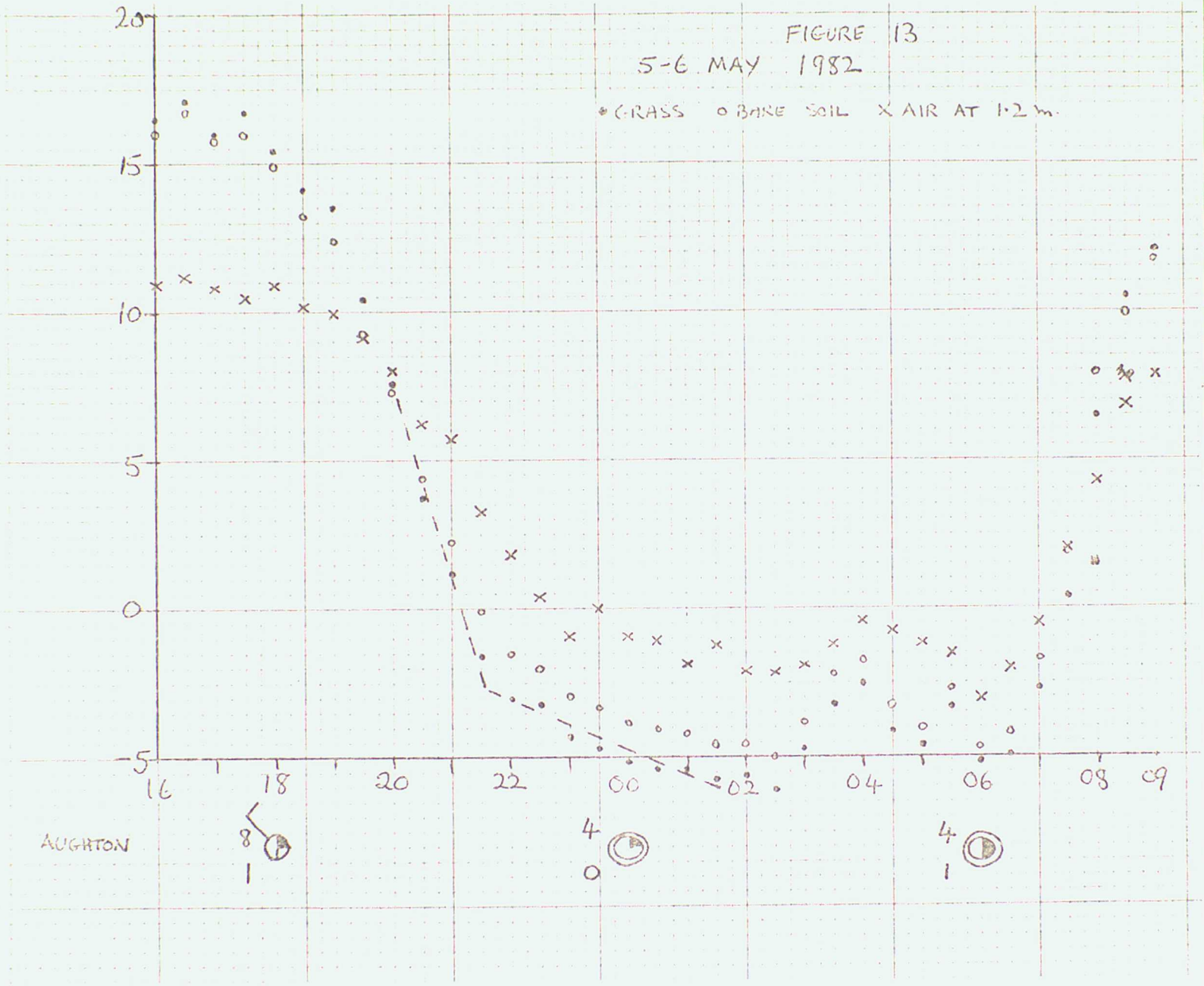


FIGURE 13
5-6 MAY 1982
• GRASS o BARE SOIL × AIR AT 1·2 m.
20
15
10
5
0
-5
16
18
20
22
00
02
04
06
08
09
AUGHTON
8
1
4
0
4
1